

STABLE ISOTOPIC STUDIES OF H,C,N,O AND S IN SAMPLES OF MARTIAN ORIGIN; I.P.Wright, M.M.Grady and C.T.Pillinger. Planetary Sciences Unit, Department of Earth Sciences, The Open University, Milton Keynes, MK7 6AA, U.K.

The present day geochemical cycles of volatile elements through the various reservoirs on Earth are largely understood within the context of the planet's standing as a geologically and biologically evolved body. Furthermore, the nature of the primitive starting materials which coalesced to form the terrestrial planets has been to some extent established from studies of meteorites; the most volatile components will eventually be investigated from cometary samples. However, the evolutionary pathways which have led from conditions in the primitive solar nebula to the current geochemical balance on Earth are obscure, due to the lack of a geological record beyond 3.8×10^9 years. Thus, there is a need to observe directly the extent to which all planets have evolved, as these bodies may preserve evidence of the sorts of processes which were in operation on the early Earth (including those reactions which led to the formation of life).

In terrestrial studies stable isotope measurements of light elements (H,C,N,O and S) can be utilized to obtain insight into the conditions prevailing during formation of rocks of various types (i.e. igneous, metamorphic and sedimentary). In addition, isotopic measurements of the atmosphere, hydrosphere etc. have contributed to the understanding of the interaction of volatile reservoirs. A few examples illustrate the uses of stable isotope measurements; (i) the partitioning of oxygen isotopes between co-existing minerals at equilibrium allows calculation of the temperature of formation or metamorphism (e.g. 1); (ii) isotopic measurements of minerals such as carbonates can be used to infer the environmental conditions during precipitation and deposition (e.g. 2); (iii) for minerals which have undergone subsolidus reaction with aqueous fluids the imprinted isotopic signatures can be used to determine the extent and nature of alteration (e.g. 3); (iv) isotopic measurements of trace constituents (e.g. carbon and nitrogen in igneous rocks) help discern the involvement of different volatile reservoirs (e.g. 4,5). As Mars has been geologically active up until recent times, and shows clear evidence for the presence of fluid processes, it is envisaged that many applications of stable isotope studies will be appropriate to materials of martian origin (rocks, fines, gases, fluids, ices) provided samples are forthcoming.

It is probable that, in the first instance, samples returned from Mars will be surface or near-surface materials rather than fresh specimens of deep-seated origin. However, if it is accepted that SNC meteorites originate on Mars (see 6 for a review of the properties and the arguments which favour a martian origin) then such samples are already available in the laboratory for study (and indeed have been studied extensively). Notwithstanding the caveats regarding the origin of SNC meteorites, it is noteworthy that light element abundance and stable isotopic studies have been used to establish (i) their uniqueness amongst meteorites, their parent

body sampling a reservoir which was slightly different from that of the Earth (7); (ii) the presence of shock-implanted atmospheric gases (8) and (iii) the existence of pre-terrestrial weathering products (9,10).

Perhaps the most important problem which could be addressed by light element studies of the sorts of specimen likely to be available from remote automatic sampling, would be the rôle of volatiles during evolution. Of fundamental importance here is the question of whether Mars was volatile-rich (11) or volatile-poor (12). An example of a specific investigation concerns the interaction of CO₂ and H₂O within the regolith and at the surface. Over the lifetime of Mars, outgassing processes are thought to have placed between 140 and 3000 mbar of CO₂ into the atmosphere (13). This is postulated to be removed largely by carbonate formation implying the presence at some point of liquid water (13). The operation of processes which involve water (a prerequisite for life) is an extremely important issue and one which demands the application of all pertinent analytical techniques. Similarly, the martian regolith is known, from Viking measurements, to be sulphur-rich (14); interestingly, laboratory studies of SNC meteorites have demonstrated a surprisingly complex sulphur chemistry, which is probably unique amongst achondrites (15,16). The isotopic fractionation displayed by sulphur in different oxidation states may well be able to constrain formation conditions.

The only reliable way to fully comprehend the effects of volatile cycling through the mantle-crust and regolith-atmosphere-polar cap systems of Mars, is by analyses of appropriate returned samples. In order to interpret the record of geological activity in martian samples it will be necessary to understand how the past, or present, surface environment may have acted to disturb the primary characteristics of the rocks. The secondary processes, implied by SNC meteorite analyses, could be assessed by material not only from diverse locations, but also from different depths within the regolith to compare with samples from outcrops and the ambient atmosphere. It should be stressed that in order to achieve successful interpretation of the data, all materials needs to be contamination-free and, as such, the experience gained from acquisition and handling of lunar samples needs to be fully assimilated into the Mars sample return program.

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